A UK Perspective on IFE

Robbie Scott[1,2]

[1]Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell Oxford, UK.
[2]Chair, UK Inertial Fusion Consortium

UK Inertial Fusion Consortium

- ~ 90 members
- 11 UK institutions

UK Fusion Landscape

Funding Bodies

- BEIS (UK govt.): Fusion Strategy & Regulation
- UKAEA: Culham Centre for Fusion Energy
  - STEP (£240M)
- STFC: Central Laser Facility
- AWE: Orion

Facilities

- Joint European Taurus (JET)
- Mega Ampere Spherical Tokamak (MAST)
- ITER
- Vulcan
- Orion
- Extreme Photonics Application Centre (£80M)

Industry

- First Light Fusion
- General Fusion

} Significant similarities to Laser Fusion

- Tokamak Energy
- Scitech Precision

Fusion Technology

- RACE: Robotics in radioactive environments
- H3AT: Tritium handling, storage, and cycle
- MRF: Fusion Materials Development
- FTF: Fusion Materials Testing

UK Inertial Fusion Landscape

Research & Training

- 7 universities
- 1 Centre for Doctoral Training @ York
- World-class High Energy Density Science

Facilities and Technology

- Central Laser Facility (CLF):
  - Laser facilities (Vulcan, Gemini, EPAC)
  - Laser technology development (DiPOLE)
  - Target manufacturing
  - Experimental training
  - Plasma Physics Group

Industry

- First Light Fusion
- General Fusion

} Significant similarities to Laser Fusion

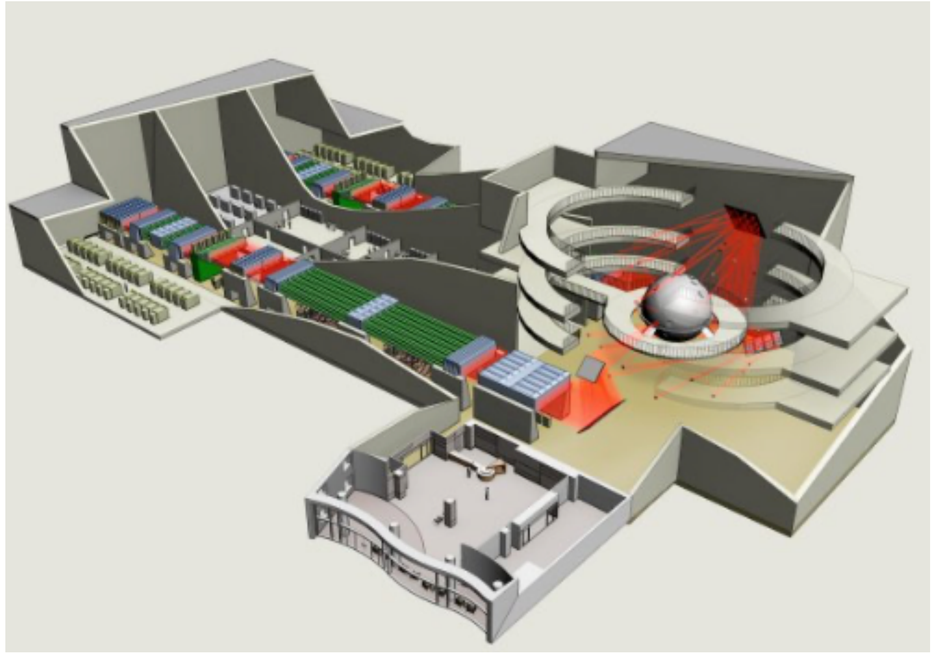
- Scitech Precision

Defence

- AWE, MoD
  - Orion laser facility
  - Significant capabilities & expertise
  - No remit for IFE research

HiPER

- CLF-led project
- Laser Inertial Fusion Energy demonstration
- Predicated on NIF ignition: Mothballed 2013
- Outputs included:
  - Technology developments: e.g. DiPOLE lasers
  - Extensive economics analyses of IFE
  - IFE chamber design
  - International collaborative research
  - …



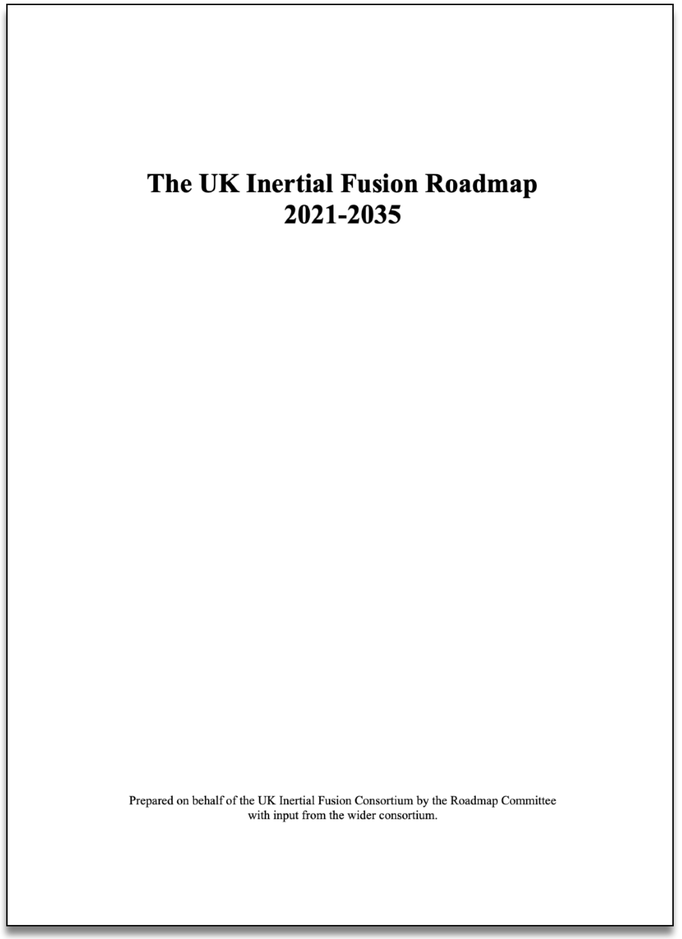
HiPER concept

UK Inertial Fusion Consortium: Goals

- Enhancing collaboration within the UK HEDS community
- Creating a common voice to facilitate dialogue with funding bodies
- Develop a commonly agreed strategy, encompassing:
  - Laser fusion/High Energy Density Physics research
  - Training the next generation
  - Developing underpinning technologies:
    - Simulation codes
    - Future laser architectures
    - Targetry

UK Inertial Fusion Roadmap

- Download from www.inertial-fusion.co.uk
- Seeks to convey a community consensus on:
  - Why IFE matters
  - The current status of IFE research
  - Recommendations for funding bodies
  - A Roadmap for future developments


The UK Inertial Fusion Roadmap
2021-2035

Prepared on behalf of the UK Inertial Fusion Consortium by the Roadmap Committee
with input from the wider consortium.

Roadmap: Technological Developments

Prototype Laser Fusion Beamline

- DiPOLE laser-driver technology:
  - Current status: Diode pumped, 10 Hz, ~150 J
  - Development to: >1 kJ level @ 3ω with increased bandwidth

Vulcan 2020

- Enhanced long-pulse capabilities ~10 kJ
- Increased shot repetition rate 1/minute
- Enhanced diagnostics

IFE Capsules

- Scitech Precision & CLF target fabrication
- Economic manufacture via microfluidics

Simulation Codes

- Critical research infrastructure
- Improved predictive capabilities
  - Improved physics models
  - Testing against multi-scale experiments

Roadmap: Strategic Developments

Training

- UK-wide High Energy Density Science training scheme
- Spanning 7 universities & labs

UK-US IFE Science & Technology Agreement

- Positive initial discussions:
  - UK government
  - DOE
- Build on existing cooperative framework

2025 UK Review of IFE

- Establish longer-term strategy
- Bring forward in the event of NIF ignition

A Future Implosion Facility

- ~ 10 year timeframe
- International funding model?
- Co-location with an XFEL?

An International Approach to IFE

✅ Proven successful long-term funding route: CERN, ITER, Astronomy

✅ Government funding: Private equity unlikely to fund projects at > $2 Bn level

✅ Various potential partners: US, UK, Europe, Japan, …

❌ Potential proliferation issues

❌ Historically slower than private companies

An International Collaborative Path Towards IFE

~ 2025

~ 2028

~ 2033

Build International Partnership

- Inter-governmental agreements
- Initial project funding

Robust Science Case

- Define driver requirements for IFE
- Using existing facilities

Detailed Facility Design

- Initial: low-rep rate design
- Rep-rate upgrade path

Construction of Prototype Beamlines

- Low-rep rate
- High rep-rate
- Upgrade path
- Cost engineering

Establish Project Site

- Partners bid

Facility Construction

- Learn from private sector to expedite

Establish Project Centre

Economic Target Manufacturing

- Readiness for high-rep upgrade

Low Energy 10 Hz Facility

- 10 Hz operations

1st Facility Phase

- Demonstration of gain required for IFE

10 Hz Upgrade

2nd Facility Phase

- High gain @ 10 Hz

²RLiFE: Towards a Reactor for Laser Inertial Fusion Energy

Science

Demonstrate ignition-equivalent implosion performance

Improve & verify UK's predictive simulation code capabilities

Quantify predictive uncertainties

Robust, uncertainty quantified, prediction of laser driver requirements for Inertial Fusion Energy

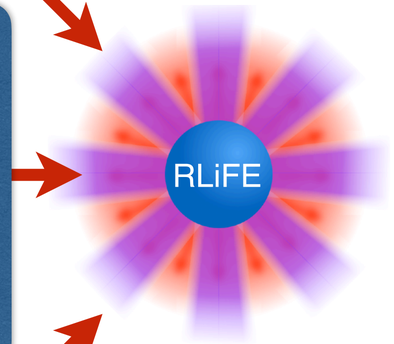
Technology

Develop high-efficiency, economic laser drivers

Develop cheap, mass-manufacturable implosion targets

Reactor designs

Fusion materials



People

Establish UK Centre for Doctoral Training in High Energy Density Science

Inertial Fusion Energy Fellowship scheme

Build upon collaborations:

UK-US

UK-Europe

Summary

Laser Fusion Physics

- Key physics of ignition are proven
- Need high-gain demonstration

UK

- World-class: research, training, technology
- Wider fusion community (CCFE, First Light, …)
  - Fusion technology
- Enthusiastic to build partnerships

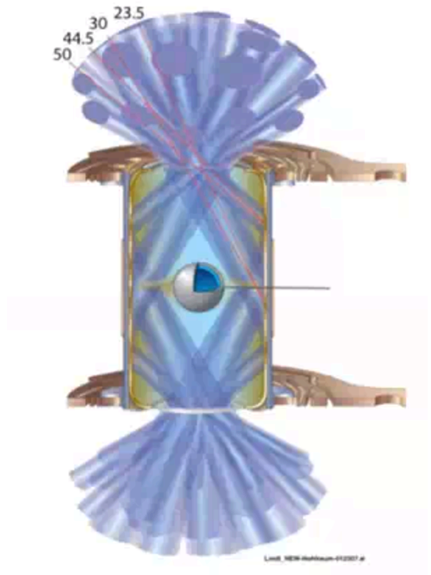
An International Approach to IFE

- Funding precedent: CERN, ITER, Astronomy…
- Multiple potential partners
- Rapid innovation through high investment

End of Slides

Inertial Fusion Energy

NIF / LMJ: ‘indirect’ drive



✅ Good for proof-of-principle

✅ Relevance to weapons

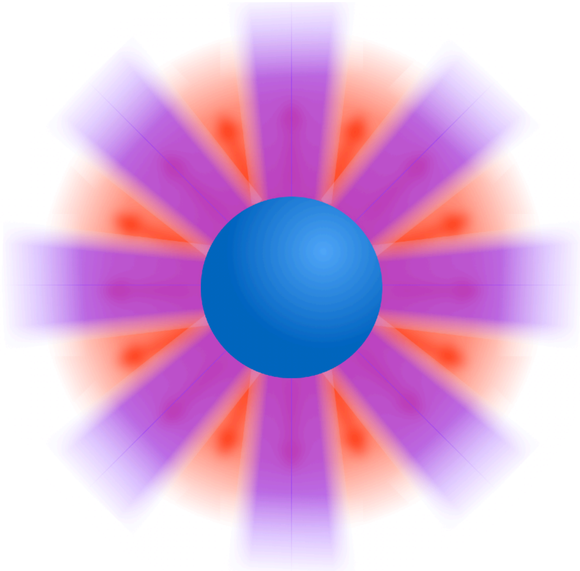
❌ Very inefficient

❌ Complex targets

❌ Expensive targets

❌ Material activation

Direct Drive



✅ 5 times higher efficiency: smaller, cheaper, laser

✅ Simple targets: economic manufacturing

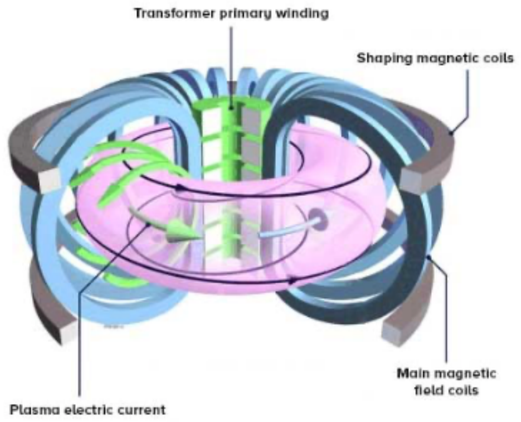
✅ High energy-gain: power-plant economics

❌ No ignition-scale laser: physics uncertainties

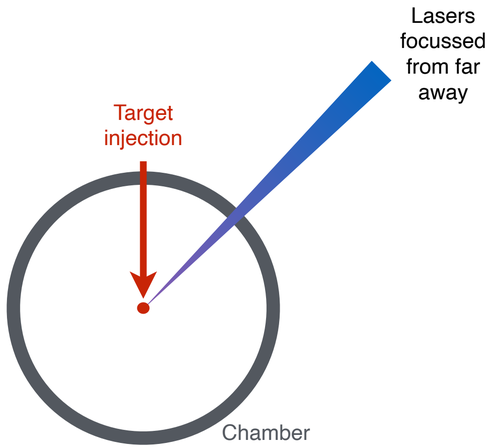
Why IFE?

- Potential technological advantages
  - Reduced neutron damage
  - Reduced thermal damage

  } Lasers enable separation between the hot plasma and critical infrastructure
  - Reduced tritium inventory (1/10th)
  - Reduced capital expenditure
  - Technological diversity
- Challenges / innovation opportunities
  - Final optics damage
  - Economic target manufacturing
- Potential strategic advantages
  - UK-US relationship
  - UK-US collaborations
  - Significant UK capabilities



Tokamak: integrated infrastructure



Laser fusion: complex components are far from fusion plasma